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Interim Guidance for UAT Avionics Operating with Safe Flight 21 ADS-B, TIS-B and FIS-B Ground Infrastructure

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1 Introduction

1.1 Background

The Federal Aviation Administration's (FAA) Capstone and Safe Flight 21 Programs are in the early stages of implementing a broadcast services ground network that will deliver to the cockpit real-time access to weather, traffic and advisory aeronautical information. Aeronautical digital communications, or data link, will provide high-speed exchange of textual and graphical information between aircraft and ground-based systems. Dedicated or multifunction avionics displays will be used to present this information to the flight crew. This implementation has begun in the Yukon Kuskokwim Delta area of Alaska under the Capstone program. Additionally, during 2004, sites are being established between Florida and New Jersey as part of the East Coast initiative as part of the Safe Flight 21 program. Subsequently, approval is being sought for a national deployment of ground infrastructure. This document is intended to address the needs of early Capstone and Safe Flight 21 implementations. This guidance may be superceded by subsequent guidance, e.g., FAA TSOs, Advisory Circulars, RTCA, and ICAO standards.

The term "Broadcast Services" encompasses three forms of broadcast information: Automatic Dependent Surveillance – Broadcast (ADS-B), Traffic Information Services – Broadcast (TIS-B) and Flight Information Services – Broadcast (FIS-B). The sections below provide a description of each form of broadcast information as well as the operational applications of this information.

The information in this document provides guidance only. Manufacturers may choose to implement any or all of these services and supporting products.

1.2 Forms of Broadcast Information

1.2.1 Automatic Dependent Surveillance –Broadcast (ADS-B)

As described in RTCA DO-242A: "ADS-B is a function on an aircraft, or surface vehicle operating within the surface movement area, that periodically broadcasts its state vector (horizontal and vertical position, horizontal and vertical velocity) and other information. ADS-B supports improved use of airspace, reduced ceiling/visibility restrictions, improved surface surveillance, and enhanced safety such as conflict management." Additional description of ADS-B is provided in Section 1.2.1 of RTCA DO-242A. See Section 1.4 below for information on the potential applications of ADS-B.

1.2.2 Traffic Information Services – Broadcast (TIS-B)

As described in RTCA DO-286, TIS-B comprises surveillance services that broadcast traffic information derived from one or more ground surveillance sources to suitably equipped aircraft or surface vehicles. TIS-B augments ADS-B by providing a more complete traffic picture in situations where not all aircraft are equipped with ADS-B. The Fundamental TIS-B Service supports enhanced visual acquisition of other aircraft by the flight crew. The ADS-B Rebroadcast Service translates ADS-B reports received on a particular data link and transmits the reports on the other available ADS-B data links.

The TIS-B system relies on various sources of surveillance information, such as Secondary Surveillance Radar (SSR). Surveillance information is processed and converted for use by ADS-B equipped aircraft. Broadcast services ground stations then transmit TIS-B messages to ADS-B equipped aircraft. The ground stations also receive ADS-B transmissions received from ADS-B equipped aircraft and convey the reports to the TIS-B system to be associated with reports obtained from other surveillance sensors.

1.2.3 Flight Information Services – Broadcast (FIS-B)

As described in RTCA DO-267, FIS-B provides the ground-to-air broadcast of non-control, advisory information needed by pilots to operate more safely and efficiently. There are numerous potential FIS-B products. For example, FIS-B products include graphical and textual weather reports and forecasts (e.g., METARs and TAFs), Special Use Airspace (SUA) information, Notices to Airmen (NOTAMs), and other aeronautical information.

Note: *Initial FIS products available are listed in Section 2.3.3.*

Note: *RTCA DO-267 provides guidance that is data link independent and applies to this service as well as other FIS-B implementations.*

The FIS-B system obtains data from various approved sources. The data are processed, formatted and delivered to appropriately equipped aircraft via broadcast services ground stations.

1.3 Data Links

The FAA has established a policy supporting two data links for broadcast services: 1090 Extended Squitter, and the Universal Access Transceiver (UAT)[1]. This document is limited in scope to the UAT implementation.

[1] See www.faa.gov/asd/ads-b for more information on the FAA Link Decision

1.4 Operational Application of Broadcast Services

1.4.1 Surveillance Information

Surveillance information received via ADS-B or TIS-B support Aircraft Surveillance Applications (ASA). As described in RTCA/DO-289: "The ASA system comprises a number of flight-deck-based aircraft surveillance and separation assurance capabilities that may directly provide flight crews with surveillance information as well as surveillance-based guidance and alerts." More information on the set of specific applications can be found in RTCA DO-289. This particular Interim Guidance document is intended to provide guidance for avionics implementations limited to support of the Basic ASA capability level (ACL) defined in DO-289 that includes Enhanced Visual Acquisition, Conflict Detection, Airport Surface Situation Awareness and Final Approach and Runway Occupancy Awareness.

Ground stations receiving ADS-B information can support Ground Surveillance Applications (GSA). One initial GSA application is ATC surveillance outside of radar coverage (see DO-289 appendix AD and DO-242A appendix D and E). This application has already been implemented in portions of Alaskan airspace. Industry standards (e.g., RTCA standards) for GSA do not exist at this time but are under development.

1.4.2 FIS Information

Section 1.3 of RTCA DO-267 describes the operational application of FIS-B data.

1.5 References

The list of documents important for the avionics implementation of broadcast services is listed below. Information in this interim guidance document is intended to supplement but not supercede the information in the referenced documents.

1. RTCA DO-282 "Minimum Operational Performance Standards for Universal Access Transceiver (UAT) Automatic Dependent Surveillance Broadcast (ADS-B)." The reference [UAT MOPS] will be used throughout this document.

Note: *An update to DO-282 is imminent as of the time this document is being finalized.*

2. RTCA DO-242A "Minimum Aviation System Performance Standards for Automatic Dependent Surveillance Broadcast". The reference [ADS-B MASPS] will be used throughout this document.

3. RTCA DO-267 "Minimum Aviation System Performance Standards for Flight Information Services Broadcast (FIS-B) Data Link." The reference [FIS-B MASPS] will be used throughout this document.

Note: *An update to DO-267 is imminent as of the time this document is being finalized.*

4. RTCA DO-286 "Minimum Aviation System Performance Standards for Traffic Information Service-Broadcast (TIS-B)." The reference [TIS-B MASPS] will be used throughout this document.

5. RTCA DO-289 "Aircraft Surveillance Applications (ASA) Minimum Aviation System Performance Standards" The reference [ASA MASPS] will be used throughout this document.

Note: *Additionally, a MOPS for Airborne Separation Assistance System (ASAS) is being developed by RTCA that will contain additional information relevant to the display and processing of traffic information.*

1.6 Scope

This paper provides guidance for avionics manufacturers, related equipment manufacturers, and other interested parties developing equipment for interaction with the FAA's Safe Flight 21 and Capstone broadcast services ground network early implementations. Specifically, this document addresses the format, data flow and interpretation of the uplink broadcast of TIS-B and FIS-B information. This document is organized according to the context diagram shown in Figure 1-1. In this diagram, the avionics implementation is shown conceptually in two parts: the functional elements responsible for transmission of ADS-B, and the functional elements responsible for reception and processing of ADS-B, TIS-B, and FIS-B information.

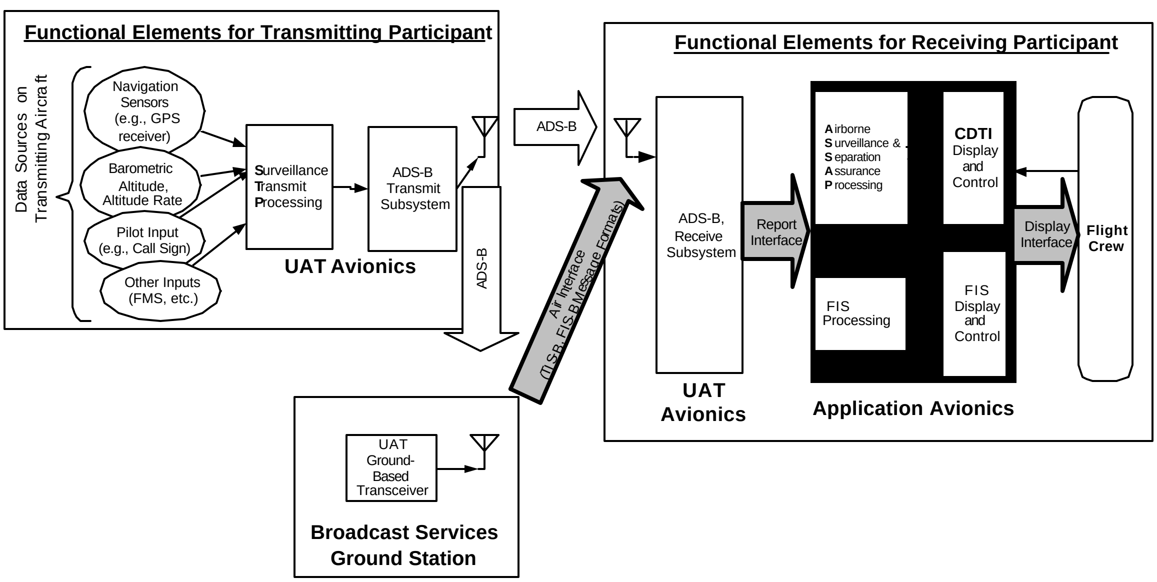

Figure 1-1: Information Flow Context Diagram

Note: *A receive-only UAT implementation is possible but is not recognized by [UAT MOPS] or [ADS-B MASPS].*

Note: *The Surveillance Transmit Processing function is outside the scope of [UAT MOPS] but will be covered in the upcoming ASAS MOPS*

This document addresses only the processing and data flow relative to the receive half of Figure 1-1. The elements labeled "UAT Avionics" collectively refers to the transmit and receive subsystems associated with the UAT data link[1]. The box labeled "Application Avionics" represents the collection of functional elements responsible for processing and display of the received information. Further background on these functional elements is given in Section 1.7.

The large shaded arrows reflect the organization and contents of the remaining major sections of this document. The left-most of these arrows represents the over air (air interface) for the uplink messages that convey the TIS-B and FIS-B information. While the majority of the information required for interpretation and processing of uplink data is contained in existing standards, Section 2 addresses a small number of details not yet covered by those standards.

Section 3 provides recommendations for format of the "report" interface. The report interface represents the output of the receive subsystem. This guidance is oriented to general aviation implementations to foster interoperability between UAT Avionics and Application Avionics from different sources. While [UAT MOPS] and [ADS-B MASPS] address information content requirements for ADS-B reports, no RTCA documents establish a standard interoperable format for the report interface.

Section 4 provides guidance for the display of surveillance and FIS data when used in an advisory context. This guidance is limited to some few aspects not yet addressed by existing standards.

1.7 Aircraft Avionics Function

The airborne avionics includes UAT data link signal processing (represented in Figure 1-1 as the UAT Avionics) and application software for the ADS-B, FIS-B and TIS-B functions (collectively represented in Figure 1-1 as the Application Avionics).

1.7.1 UAT Data Link Signal Processing for ADS-B, TIS-B and FIS-B

1.7.1.1 UAT System Overview

Background information on UAT relative to message types, message structure, medium access and message scheduling can be found in Section 1.3 of [UAT MOPS].

[1] The terms "ADS-B Transmit Subsystem" and "ADS-B Receive Subsystem" are generic terms used in RTCA documentation. In the case of UAT, the receive subsystem naturally supports reception of ADS-B, TIS-B and FIS-B.

1.7.1.2 UAT Data Link Signal Processing

UAT implementations will normally consist of transmit and receive subsystems. Most configurations will include both subsystems; however, transmit-only configurations are also possible in accordance with [ADS-B MASPS].

Note*: A receive-only UAT equipment configuration is possible but is not recognized by [UAT MOPS] or [ADS-B MASPS].*

The UAT ADS-B Transmitting Subsystem composes and transmits one ADS-B message each second according to the procedures of Section 2.2.6 and 2.2.7 of [UAT MOPS].

The UAT ADS-B Receiving Subsystem generates reports in response to messages received over the UAT air interface according to the procedures of Sections 2.2.8, 2.2.9, and 2.2.10 of [UAT MOPS].

1.7.1.3 UAT ADS-B Equipage Classes

RTCA has categorized ADS-B equipment into aircraft system equipage classes as defined in [ADS-B MASPS]. This categorization is based on potential ADS-B applications and the needs of particular airspace users. This categorization, as it applies to UAT, is detailed in Section 2.1.11 of [UAT MOPS].

1.7.2 Application Avionics Functional Elements

The major functional elements of the Application Avionics identified in Figure 1-1 are described in the subparagraphs below.

1.7.2.1 Airborne Surveillance and Separation Assurance Processing (ASSAP)

ASSAP is the processing subsystem that accepts surveillance inputs, performs surveillance processing to provide reports and tracks, and performs application-specific separation assurance processing. Surveillance reports, tracks and any application-specific alerts or guidance are output by ASSAP to the Cockpit Display of Traffic Information (CDTI) function (see [ASA MASPS.] for further detail).

1.7.2.2 Cockpit Display of Traffic Information (CDTI).

The CDTI subsystem includes the actual display media and the necessary controls to interface with the flight crew. The CDTI control panel may be a dedicated control panel or it may be incorporated into another control, e.g., multi-function control display unit (MCDU). Similarly, the CDTI display may also be a stand-alone display (dedicated display) or the CDTI information may be presented on an existing display (e.g., multi-function display).

The CDTI provides the platform for displaying position (e.g., latitude, longitude, and altitude) and track data for nearby aircraft and vehicles. CDTI can receive traffic data from multiple sources (e.g., ADS-B, TIS-B) via the ASSAP function to support ASA applications. Terrain information, moving maps with own-ship position, and other situational awareness information may also be depicted on this display.

1.7.2.3 FIS Processing

Guidance for processing and presentation of FIS information is provided in Section 3.8.1 of [FIS-B MASPS].

1.7.3 Safety Assessment Considerations.

System Safety Assessment. FAA certification staff may require that the applicant conduct an aircraft safety assessment to comply with applicable sections of §§ xx.1301 and xx.1309 of 14 CFR parts 23, 25, 27, and 29. Where the CDTI is to be used for guidance and control, the failure condition classification has historically been shown to be at least MAJOR for misleading information. The failure condition classification for loss of function has historically been shown to be at least MINOR. Lower classifications shall be substantiated by a safety analysis. More complex or integrated systems such as TCAS II and ADS-B may have higher failure condition classifications based upon the results of the airplane-level functional hazard assessment. For airborne systems that will not be used in support of IMC operations and are developed only for enhanced traffic awareness (e.g., traffic advisories for see and avoid) operations, the failure condition classification for misleading information is considered MINOR and loss of the function has NO SAFETY EFFECT. For airborne systems that will be used to support cockpit displays of advisory FIS-B products, the failure condition classification for misleading information is considered MINOR and loss of the function has NO SAFETY EFFECT, as specified in Section 2.1.1 [FIS-B MASPS].

FAA advisory circulars 23.1309-1C, 25.1309-1A, 27 1B/ 29-2C (or later FAA approved versions) provide aircraft safety assessment guidance for other system safety issues for general aviation, transport category, and rotorcraft, respectively.

Additional SSA requirements are found in the applicable sections xx.1309 of 14 CFR parts 23, 25, 27, and 29. Acceptable methods for performing a safety assessment are contained in Society of Automotive Engineering (SAE) Aerospace Recommended Practices (ARP) 4754 “Certification Considerations for Highly-Integrated or Complex Aircraft Systems” and SAE ARP 4761 “Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment”.

1.7.4 Software development assurance for airborne displays (ADS-B, TIS-B, FIS-B) and transmission of ADS-B own-ship information.

(1) **Software standards.** The AC 20 115B invokes RTCA/DO-178B, which provides an acceptable means for showing compliance to applicable airworthiness regulations for the software aspects of the aircraft airborne avionic systems. Once the aircraft system failure condition classification has been determined and the software level assignment has been substantiated, AC 20 115B, Software Design Considerations (RTCA DO 178B) should be used to provide a methodology for software design assurance.

(2) **Software levels for the transmission of ADS-B own-ship information**. Based on existing transponder certification guidance, software for the transmission of data pertaining to one's own-ship information has been historically developed to at least Level C criteria, as defined in RTCA/DO-178B. The software implementation of transmission of own-ship data has at least a major failure classification. However, if the ADS-B system is integrated with other aircraft functions, a higher software level may be appropriate, based on the results of the aircraft level safety analysis.

(3) **Software levels for the display of traffic information.** The software levels for display of traffic information will be determined during the system safety assessment process as described above.

(4) Software levels for FIS-B airborne displays. Based on existing FIS-B certification guidance, the applicant may develop all software for the display of FIS-B advisory information to at least Level D criteria, as defined in RTCA/DO-178B. Advisory information products include but are not limited to graphical and textual weather reports and forecasts, (e.g., METARs and TAFs), Special Use Airspace (SUA) information, and Notices to Airmen (NOTAMs).

Electronic Hardware design assurance

If any functions are implemented using complex electronic hardware whose failure conditions are classified as Major, Hazardous, or Catastrophic, the design of such hardware **should** be assured by a methodology acceptable to the FAA. Additionally, once the assurance levels are assigned by the safety assessment, it should be verified that the hardware and software design assurance levels are compatible to each other.

2 UAT Air Interface

2.1 Waveform

Aircraft transmitters and ground station transmitters both use the same UAT waveform characteristics. Specifics on the UAT waveform can be found in Section 2.2.2 of [UAT MOPS].

2.2 Message Formats

UAT over-the-air messages contain two fundamental components: the *overhead*, principally consisting of forward error code parity that supports the transfer of the data and the *payload* that carries the application data used by applications.

2.2.1 ADS-B Message

The UAT employs two formats of ADS-B message. One is the "Basic" ADS-B message format and the other is the "Long" ADS-B message format. ADS-B messages in the Basic format convey only the basic and rapidly changing information such as identity, position and velocity. ADS-B messages in the Long format convey the basic information plus additional information as required for a given installation or operational use. Each second a given UAT-equipped aircraft will transmit a single ADS-B message in one or the other format depending on the required payload content.

Section 2.2.3.1 of [UAT MOPS] completely describes the information content and format of the payload of ADS-B messages that are transmitted by aircraft and received air-air.

2.2.2 TIS-B Message

TIS-B messages uplinked by UATs at broadcast services ground stations will use the ADS-B message format. TIS-B targets may be represented by either the Basic or Long ADS-B message format as required by the TIS-B information to be conveyed.

Note*: Even though TIS-B target updates will be transmitted by ground stations using the ADS-B message format, the term "TIS-B message" will be used in this document to distinguish this from ADS-B messages that are transmitted by aircraft.*

The fields of the payload of the TIS-B message that have special relevance to the TIS-B services are listed below:

a. ADDRESS QUALIFIER: TIS-B messages are distinguished from other ADS-B transmissions through the "ADDRESS QUALIFIER" field (Section 2.2.4.5.1.2 of [UAT MOPS]). An ADDRESS QUALIFIER of "2" indicates the TIS-B system has knowledge of, and is providing, the traffic's 24-bit ICAO address in the TIS-B message[1]. An ADDRESS QUALIFIER of "3" indicates the TIS-B system does NOT know the 24-bit ICAO address assigned to the target aircraft. Instead the 24-bit ADDRESS field represents a "Target Address" that is guaranteed to be unique within the domain of the control facility generating the TIS-B report. All other values for the ADDRESS QUALIFIER indicate transmissions directly from the aircraft, surface vehicle, or obstacle transmitter.

b. TIS-B SITE ID: The STATE VECTOR Element of the ADS-B message is encoded in the format shown in Section 2.2.4.5.3 of [UAT MOPS] which includes the "TIS-B SITE ID" field. The "TIS-B SITE ID" field is used to allow the airborne application to associate each received TIS-B message with the ground station from which it was transmitted. No use of this information is recommended by avionics supporting advisory level services at this time.

All other fields in the TIS-B message payload are consistent in their encoding and interpretation with that of ADS-B.

2.2.3 Ground Uplink Message

The UAT Ground Uplink message is a general purpose mechanism used primarily for the uplink of FIS data. Each Ground Uplink message contains a 432 byte payload field. The Ground Uplink Payload is composed of an eight-byte UAT-Specific Header, followed by 424 bytes of Application Data. The UAT Ground Uplink message header format is defined in Section 2.2.3.2 of [UAT MOPS]. The Application Data field is composed of one or more Information Frames (I-Frames). The decomposition of the Ground Uplink message payload is shown in Figure 2-1.

Note*: Information in Sections 2.2.3.2 through 2.2.3.3 below will be incorporated in the next update to [UAT MOPS]*

Note*: An aggregate net throughput (after overhead) of 108 Kbps is available to be shared among all ground stations. It is expected that most of this will be available for FIS products. This guidance does not address the prioritization of product distribution or quality of service.*

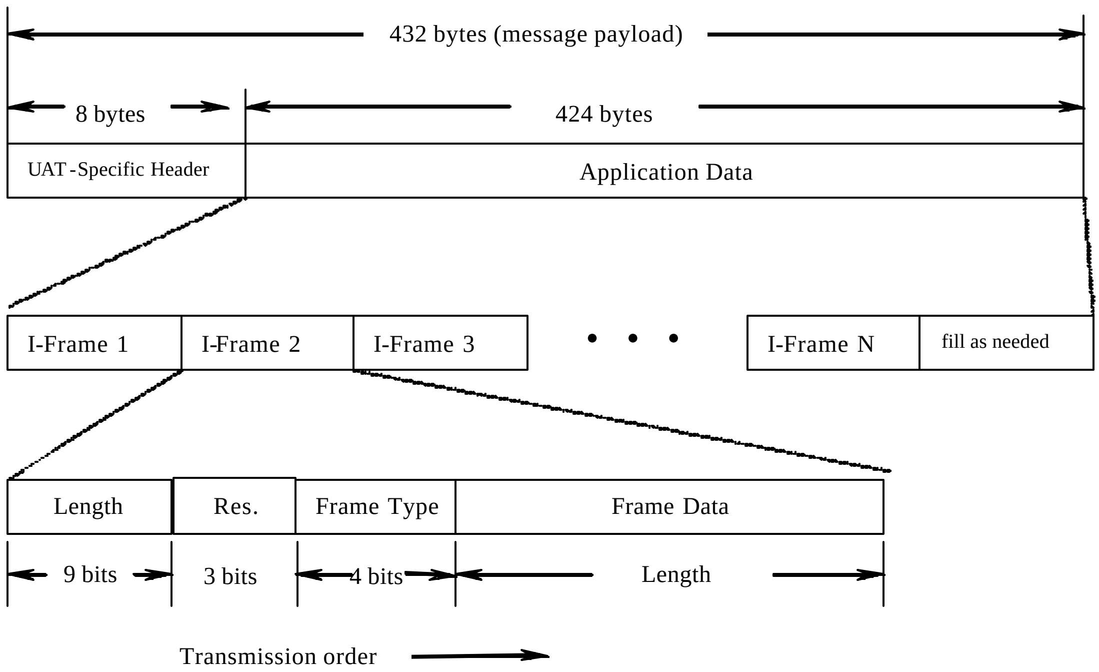

Figure 2-1: Decomposition of the Ground Uplink Message Payload

2.2.3.1 UAT-Specific Header

The UAT-Specific Header is an 8-byte field that contains information on the location of the broadcasting ground station, the time slot used to send the present message, validity flags for position, time, and application data, and other fields as described in Section 2.2.3.2.2 of [UAT MOPS].

2.2.3.2 Application Data

The Application Data is a fixed-length field of 424 bytes. The Application Data consists of Information Frames, and always consists of an integral number of bytes. Any remaining unused portion of the field is zero-filled (i.e., all bits set to ZERO).

Note: The Application Data should be discarded if the Application Data Valid field is set to "0" in the UAT-Specific Header, as specified in [UAT MOPS].

2.2.3.3 Information Frames

Each Information Frame consists of 'N' bytes, comprising four fields formatted as shown in Table 2-1.

Table 2-1: Frame Structure

<table>
<tr><th>Byte #</th><th>Bit 1</th><th>Bit 2</th><th>Bit 3</th><th>Bit 4</th><th>Bit 5</th><th>Bit 6</th><th>Bit 7</th><th>Bit 8</th></tr>
<tr><td>1</td><td>MSB</td><td colspan="7">Length</td></tr>
<tr><td>2</td><td>LSB</td><td colspan="3">Reserved</td><td>MSB</td><td colspan="2">Frame Type</td><td>LSB</td></tr>
<tr><td>3
-
N</td><td colspan="8">Frame Data</td></tr>
</table>

Notes:

1. *Byte numbers in this table are relative to the beginning of the current Information Frame.*
2. *Within each byte, bit 1 is transmitted first and bit 8 is transmitted last*

2.2.3.3.1 Length Field

The Length field (Byte 1: Bit 1 through Byte 2: Bit 1) is a 9-bit field that contains the length of the Frame Data field in bytes. Values range from 0 through 422 (decimal). The Length value is always equal to 'N-2'.

***Note**: When Information Frames do not fully occupy the Application Data field, the unused portion is zero filled. When encountered by the frame parsing logic, the zero fill portion will appear as a frame of zero bytes in length or an incomplete frame if less than 2 bytes remain. This would be the indication to the parsing logic that the last frame has been found.*

2.2.3.3.2 Reserved Field

The Reserved field (Byte 2: Bits 2 through 4) is a 3-bit field that is reserved for future use, and will be set to ALL ZEROES.

2.2.3.3.3 Frame Type Field

The Frame Type field (Byte 2: Bits 5 through 8) is a 4-bit field that contains the indication for the format of the Frame Data field. The Frame Types are defined in Table 2-2.

Table 2-2: Frame Types

MSb **Value** (binary) LSb	**Frame Data Format**
0000	FIS-B APDU
0001 - 1110	Reserved for future use
1111	TIS-B Signaling[1]

[1] This entry is labeled as "Reserved for developmental use" in the proposed update to [UAT MOPS]).

When the Frame Type is the binary value “0000”, the Frame Data contains FIS-B data packaged as an Application Protocol Data Unit (APDU) as described in Section 3.6, and Appendix D of [FIS-B MASPS]. When the Frame Type is the binary value “1111”, the Frame Data contains TIS-B signaling information (see Section 4.1.3.2.1). Fourteen reserved values remain for future use.

2.2.3.3.4 Frame Data Field

The Frame Data field conveys the basic units of uplink application data. For FIS-B this data unit is known as the Application Protocol Data Unit (APDU) as defined in [FIS-B MASPS].

2.3 FIS Product Encoding (APDUs)

Each APDU will be transmitted with an APDU Header followed by the APDU Payload.

2.3.1 APDU Header

The APDU header format with options is as described in Appendix D of [FIS-B MASPS] with one exception as described below.

The over-air format of the APDU header does not include the 16 bit FIS-B APDU ID field. Per [FIS-B MASPS], this field is a fixed two byte field of 0xFF and 0xFE. Since FIS-B APDUs are fully identified as such by the Frame Type field (Section 2.2.3.3.3), transmission of these 2 bytes over the air interface are unnecessary. If this two byte field is required for interoperability reasons on board the aircraft, this two byte field can be reconstituted after receipt onboard.

2.3.2 APDU Payload

APDUs will carry products that are registered in the FAA’s FIS-B product registry. This registry is maintained by the Weather Processor and Sensors Group at the FAA’s William J. Hughes Technical Center. The registry can be accessed at http://fpr.tc.faa.gov.

The FAA Broadcast Services ground system presently encodes FIS data for uplink using only *independent* APDUs as described in [FIS-B MASPS]. In the event that future FIS-B products require an APDU longer than 422 bytes, then the linked APDUs described in [FIS-B MASPS] may be used.

Two important characteristics of these APDUs are as follows:

- Each independent APDU stands alone in that each individual APDU received results in some data that can be rendered on the cockpit display; there is no dependence on the APDUs that precede or succeed it.
- Applications have no need to know which ground station was the one that uplinked an APDU; the APDU Application Data is ground station independent.

2.3.3 Initial Products

2.3.3.1 Textual METAR and TAF Products

The Textual METAR and TAF products will use the format identified in the FIS-B product registry by the name "Generic Textual Data Product - Type 2 (DLAC)" and the 11 bit Product ID of "413" (decimal). Details on the encoding of the text records are found in the FAA's FIS-B product registry (http://fpr.tc.faa.gov).

2.3.3.2 NEXRAD Graphic Product

The NEXRAD Graphic product is identified in the FIS-B product registry by the name "Global Block Representation – NEXRAD, Type 4 – 8 Level" and the 11 bit Product ID of "63" (decimal). Details on the encoding of the text records are found in the FAA's FIS-B product registry (http://fpr.tc.faa.gov).

2.3.4 Future Products

Bandwidth exists to accommodate additional products and FAA has plans to implement additional products. FAA will announce the availability of new products when they are ready for operational use. New products will be described in the FAA FIS-B product registry.

3 Report Interface Guidance

3.1 Background

This Section provides an example report interface format for the UAT equipment. Specifically, this is the report interface between the UAT Avionics and the Application Avionics to provide reports that are a direct result of messages received over the UAT air interface[1]. This guidance is targeted primarily for general aviation implementations to foster an open report output interface for UAT radio equipment

This Section describes a reference interface comprising a set of application-level reports that are constructed using a standardized packet format. Also presented is an example of this interface with link-layer encapsulation using frames based on an HDLC format. This reference interface provides for delivery of received ADS-B and TIS-B traffic, ADS-B ownship position, and FIS-B uplinks to Application Avionics.

***Note**: This guidance does not apply to integrated implementations where no external interface is required.*

3.2 Composing "Reports"

The UAT report assembly function is implemented as a "pipeline" for delivery of message payloads received via the UAT Avionics and augmented with appropriate report fields.

As indicated in Section 2.2.9 of [UAT MOPS], the Time of Message Receipt (TOMR) field is added to the received information by the UAT equipment. TOMR has sufficient resolution and span to resolve the time reference for the received message. Absolute time is not necessary if the Application Avionics has access to its own absolute time reference. The TOMR value is the high-accuracy time measurement within the current second, which may be used by an external application for range measurement and validation.

3.3 Report Packet Format

Table 3-1 shows the recommended definition of a report packet format and Table 3-2 shows the recommended set of report packet types.

[1] The "report" interface is essentially one way from the UAT Avionics to the Application Avionics. Various required inputs to the UAT Avionics (e.g., position, velocity, time etc) are not addressed here even though they may share the same physical interface with the report interface.

Table 3-1: Report Packet Format

# of Bytes	Content
1	Packet Type (defined in Table 3-2 below)
4	Time of Message Receipt (units of hundreds of nanoseconds since UTC midnight modulo 25.6 seconds)
Variable	UAT Message Payload (see Table 3-2 below)

Notes:

1. *Fields are listed in order of transmission.*

2. *Multi-byte fields are transmitted most significant byte first.*

Table 3-2: Report Packet Types

Packet Type #	Report Packet Type	Content
0	Status	Periodic status report of UAT performance (Note 1)
1	Traffic Report resulting from ADS-B message reception by UAT Avionics (Note 2)	18 or 34 bytes, format as defined in Table 2-8 of [UAT MOPS].
2	Ownship Report resulting from ADS-B message transmission by UAT Avionics	18 or 34 bytes, format as defined in Table 2-8 of [UAT MOPS].
3	Ground Uplink Report resulting Ground Uplink message reception by UAT Avionics	432 bytes of payload data; header format as defined in Table 2-4 of [UAT MOPS]. Application Data is composed of I Frames per Section 2.2.3.3.
4-127	Reserved for manufacturer-specific packets	

Notes:

1. *Items that may be included in the Status Packet Type include: GPS time in seconds since midnight (full resolution), number of ADS-B and Uplink messages decoded successfully, and the number of reports discarded in the previous second due to report interface capacity. No operational use of any information that may be provided in a Status report is being recommended in this document.*

2. *Traffic Reports include both ADS-B received direct air-air and TIS-B received ground-air.*

3.4 Link Layer

The example data link layer frame format is based on the High-level Data Link Control (HDLC) link frame as shown in Table 3-3. Transmission using byte-orientation is recommended in order to support asynchronous serial communications (this relates to the procedures used for "data transparency"—see Section 3.4.1). Each field in Table 3-3 is discussed in the following subsections to determine its applicability in implementing the Report Interface.

***Note**: The link layer frame format based on HDLC described in this section for the UAT report interface is distinct from the Information Frame format used within the Application Data field of the UAT Ground Uplink message.*

Table 3-3: Typical HDLC Link Layer Frame Format

Flag (Section 3.4.1)	**Address** (Section 3.4.2)	**Link Control** (Section 3.4.3)	**Information** (Section 3.4.4)	**FCS** (Section 3.4.5)	**Flag** (Section 3.4.1)
1 byte	1-4 or 8 bytes	1 byte	N bytes	2 bytes	1 byte

3.4.1 Flag Field

The frame starts and ends with a "Flag" octet, which is used for framing. The flag octets have the value "01111110" binary. [FIS-B MASPS] provides for two alternative procedures for ensuring data transparency (i.e., dealing with occurrences of the flag octet within the frame). The procedure designed to support asynchronous (byte-oriented) transmission is the method recommended. This asynchronous data transparency procedure is described in Section 3.4.3.2 of [FIS-B MASPS].

3.4.2 Address Field

Since this link layer is likely to be supporting a dedicated point-point connection between the UAT Avionics and the Application Avionics, address information is not required to support the data transfer.

***Note**: The Address Field in a minimal form may be included to maintain compatibility with standard frame format*

3.4.3 Link Control Field

One encoding of the Link Control Field is to identify an Un-numbered Information (UI) frame. The UAT equipment interface is only required to support UI frames, since the UAT datalink is inherently suited for only data broadcasts. Therefore, it is recommended that inclusion of a Link Control Field in the report interface is not necessary.

***Note**: The Link Control Field may be included to maintain compatibility with standard frame format.*

3.4.4 Information Field

The report packets defined in Section 3.3 above represent the Information Field of the HDLC link layer frame. One report packet is conveyed in each link layer frame.

3.4.5 Frame Check Sequence

This field contains the two octet Frame Check Sequence specified in [FIS-B MASPS].

3.4.6 Example Link Layer Frame Format

Figure 3-1 shows the example link layer frame format for the UAT report interface.

Flag (Section 3.4.1)	**Information** (Section 3.4.4)	**FCS** (Section 3.4.5)	**Flag** (Section 3.4.1)
1 byte	N bytes	2 bytes	1 byte

Packet Type (Table 3-2)	**TOMR** (Section 2.2.9 of UAT MOPS)	**UAT Message Payload**
1 byte	4 bytes	N-5 bytes

Figure 3-1: Example Link Layer Frame Format for UAT Report Interface

4 Display Interface Guidance

This section provides guidance for the display of surveillance and FIS data when used in an advisory context. This guidance is limited to some few aspects not yet addressed by existing standards.

4.1 Considerations for Display of Traffic

Traffic information on a cockpit display can come from ADS-B and TIS-B simultaneously. Considerations for the processing and display of ADS-B and TIS-B are provided in this section.

4.1.1 Associating ADS-B and TIS-B Reports

Normally the Fundamental TIS-B service will suppress TIS-B reports representing traffic that are transmitting ADS-B. One exception is the case when an ADS-B equipped target is in surveillance coverage, but in an area of marginal or no radio frequency (RF) coverage for the UAT ground station network. In order to deal with such exception cases, it is recommended that avionics attempt to prevent the depiction of duplicate target symbols for the same traffic. Specifically, it is desirable to check each TIS-B message reception to ensure it is not representing traffic that is being received via direct ADS-B air-air. This is because ADS-B messages will generally be more accurate and have less latency than the corresponding TIS-B message. Preventing the TIS-B message reception from “updating” a recent ADS-B reception (i.e., within 5 seconds) will help maintain stability of the displayed traffic symbol.

Note*: Specific detailed requirements on the correlation of TIS-B and ADS-B targets will be specified in the upcoming ASA MOPS being produced by RTCA. General requirements from [ASA MASPS] should be considered.*

4.1.2 Recommendations for Traffic Symbology and Updating

See [ASA MASPS] section 3.3.3 for guidance on CDTI displays. See [ASA MASPS] Section 2 and Table 2-3 for requirements on traffic information integrity, accuracy, etc. supporting enhanced visual acquisition, conflict detection, and airport surface situational awareness.

Note*: The upcoming ASAS MOPS will provide further detail on CDTI requirements.*

The following is a list of additional recommendations for the display and updating of traffic information.

- FAA ground stations may broadcast ADS-B messages with an ADDRESS QUALIFIER field indicating “Fixed ADS-B Beacons”. This would usually be at low power for purposes of monitoring the ground infrastructure. Any receptions of Fixed ADS-B Beacons by avionics need not be displayed on the traffic display.
- Symbols representing obstacles should be distinct from those representing aircraft or surface vehicles.

4.1.3 Special Considerations for TIS-B Traffic

TIS-B is a set of surveillance services that derives traffic information from one or more ground surveillance sources and broadcasts to ADS-B equipped aircraft or surface vehicles. The TIS-B system physical architecture is expected to include both regional control facilities and ground broadcast stations. TIS-B *control facilities* are where surveillance processing and report generation and distribution are performed for the TIS-B system, such that all targets are registered relative to each other (i.e., "fused" in areas of sensor overlap) and are identified uniquely. TIS-B services will be available where there is both adequate surveillance coverage from ground sensors and adequate Radio Frequency (RF) coverage from ground broadcast stations. The TIS-B service will uplink individual messages in the UAT ADS-B message format—one or more for each TIS-B target update—consistent with the format description in [UAT MOPS].

4.1.3.1 Spatial and Temporal Redundancy of Uplinked TIS-B Messages

The Fundamental TIS-B service will use the FAA's existing network of surveillance sensors—en route and terminal radar systems[1]. All surveillance sensors within the area of a regional control facility will be "fused" into a single traffic picture by a fusion tracker system at the control facility. A TIS-B Server will provide a stream of TIS-B reports to each individual ground station in the area via an appropriate filtering mechanism. In areas rich in ground stations and surveillance sensors, a key objective of the filtering mechanism is to carefully tailor the TIS-B traffic information sent to each ground station such that there is limited overlap (i.e., spatial redundancy) to maintain continuity of service when transitioning between ground stations. This spatial redundancy is carefully limited because it adds self interference to the data link system as seen by an aircraft at altitude. The ground system will generally provide an overlap region for TIS-B traffic information between adjacent ground stations of 5-10 NM.

In some situations, each UAT ground station may make multiple transmissions of the same TIS-B message to provide temporal redundancy. This "repeat" procedure will be most useful in situations where radar surveillance inputs to TIS-B are infrequent (e.g., long range radars), making successful receipt of each update by the TIS-B customer more important. The TIS-B Control Facility will make a best effort to transmit all copies of the same TIS-B Report in the same UAT epoch so that they have a common Time of Applicability as perceived by the UAT avionics.

Considerations for the Application Avionics in dealing with both spatial and temporal redundancy are listed below:

- The message payloads of redundant TIS-B messages will be totally identical and are therefore easily identified as such by the Application Avionics. Specifically, no position extrapolation is performed in the ground system.

[1] The term "TIS-B" encompasses the rebroadcast of ADS-B from one data link to the other (i.e., from 1090 Extended Squitter to UAT and vice versa). However, the paragraphs that follow are limited in scope to TIS-B when it provides surveillance based on radar.

- For repeat transmissions, there is a small risk that one or more of the redundant transmissions will be received in the UAT epoch that is one second later than the true Time of Applicability. The avionics will not be able to detect this condition absent receipt of the original transmission in the applicable second. This may limit the ADS-B applications for which the initial TIS-B service can be certified.

Note*: Identifying and discarding redundant messages will improve the display of TIS-B traffic when the Application Avionics displays extrapolated positions between actual updates as required by [ASA MASPS].*

4.1.3.2 Providing the Pilot an Indication of TIS-B Service Status

In certain TIS-B service areas, the FAA will be able to provide a relatively comprehensive traffic information picture to pilots via TIS-B. For this reason, it is highly desirable for the TIS-B system to support a *TIS-B service status* indication so that pilots will know when the traffic picture in the immediate proximity can be expected to be reasonably complete and when there should be no such expectation. This section describes the concept along with recommended procedures for the avionics to provide the service status indication to the pilot. No similar expectation of a relatively complete traffic picture can exist for ADS-B (for some time at least) due to its dependence on ADS-B equipage.

Note: *The TIS-B service will not provide information on traffic that is not visible to the ground surveillance system, i.e., unequipped aircraft.*

4.1.3.2.1 TIS-B Signaling

TIS-B messages are not needed to represent traffic that is ADS-B equipped since it is assumed that ADS-B equipped traffic will be adequately represented via direct air-air ADS-B reception. However, the TIS-B ground system will uplink TIS-B signaling information for ADS-B equipped aircraft—at a low average rate—for the purpose of providing a service status indication. The only signal type defined at this time will be referred to as a “heartbeat” signal. The heartbeat signal is provided periodically as a positive indication to the TIS-B customer that TIS-B service is available. Conversely, lack of any heartbeat signal for a certain interval—referred to as the `HEARTBEAT_TIMEOUT` interval—indicates that service is NOT AVAILABLE.

The heartbeat signal is conveyed in the UAT Ground Uplink message as a list of TIS-B customer addresses to which the signal pertains. The frame type identifier “15” is used for this purpose (see Table 2-2). Four bytes are used to represent each heartbeat signal and individual heartbeat signals are packed sequentially for uplink into the Frame Data portion of the Information Frame as described in Section 2.2.3.3. The format of an individual TIS-B signal is shown in Table 4-1. A single Ground Uplink message could convey a maximum of 105 TIS-B signals if all payload of the Ground Uplink message is used for signaling. This assumes all 105 signals were packed into a single Information Frame.

Table 4-1: Format of Individual TIS-B Signal

Transmn order	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
1st	**Reserved**				**Sig.**	**Address Qualifier**		
2nd	(MSB) A1	A2	A3	. . .				
3rd	**Address**							
4th					. . .	A22	A23	A24 (LSB)

.
.

When the SIGNAL TYPE bit is “1”, the signal is a heartbeat signal: service is available. When the SIGNAL TYPE bit is “0”, the signal is a “goodbye” signal: service is not available. Initially, the ground system will provide only the “heartbeat” signal. Section 4.1.3.2.2. on avionics processing uses the heartbeat signal only.

The presence of a heartbeat signal for a TIS-B customer indicates that TIS-B service should be available for traffic in the immediate proximity. Upon entry into airspace where the TIS-B system has both surveillance coverage AND UAT ground station coverage (i.e., ADS-B downlinks received), heartbeat messages are transmitted. To aid the TIS-B customer to initially acquire their heartbeat messages, the transmission rate may initially be high for a short period (e.g., a rate similar to TIS-B message rate used to represent traffic). Subsequently, the rate is decreased to a low rate used only to “hold up” the service available indication. This low rate would be established to ensure at least one heartbeat reception by the TIS-B customer every `HEARTBEAT_TIMEOUT` seconds. It is recommended that avionics treat the `HEARTBEAT_TIMEOUT` as a parameter with a factory default of 60 seconds.

Note: *As experience is gained with the TIS-B service, it may be desirable to use a timeout value other than the default. In the future, it is expected that the TIS-B function will broadcast a HEARTBEAT_TIMEOUT value that would override the default.*

4.1.3.2.2 Avionics Processing to Determine TIS-B Service Status

It is recommended that at least the two TIS-B service status indications listed in Table 4-2 are supported.

Table 4-2: TIS-B Service Status Indications

TIS-B Service Status Indication	Meaning
“AVAILABLE”*	TIS-B customer can expect updates on traffic in the immediate proximity with reasonable confidence.
“NO SVC”*	TIS-B customer should not expect updates on traffic in the immediate proximity

* *These are example annunciations only; any equivalent annunciations that convey the intended meaning may be used*

Figure 4-1 illustrates the conditions for both of the service status indications relative to the TIS-B Service Volume. The term “TIS-B Service Volume” as used in this document represents the intersection of the *Surveillance Coverage Volume* and the UAT *Ground Station Service Volume* where these latter terms in italics are described in [TIS-B MASPS].

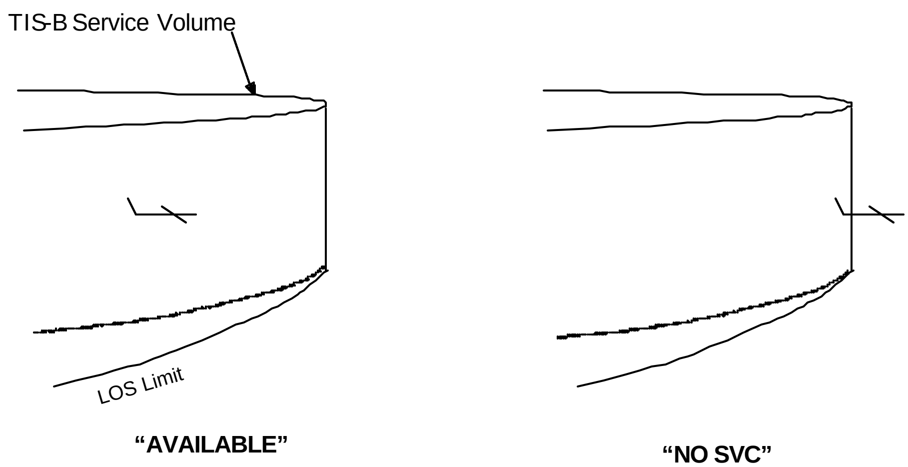

Figure 4-1: Illustration of TIS-B Service Status

While Figure 4-1 shows the customer aircraft exiting service through a lateral boundary in the TIS-B service volume, a more typical case is likely to be when the customer aircraft descends through the line-of-sight floor of the TIS-B service volume. This could be a common situation when a UAT ground station is sited at an airport location where the nearest surveillance radar is some distance away. Figure 4-2 shows this case.

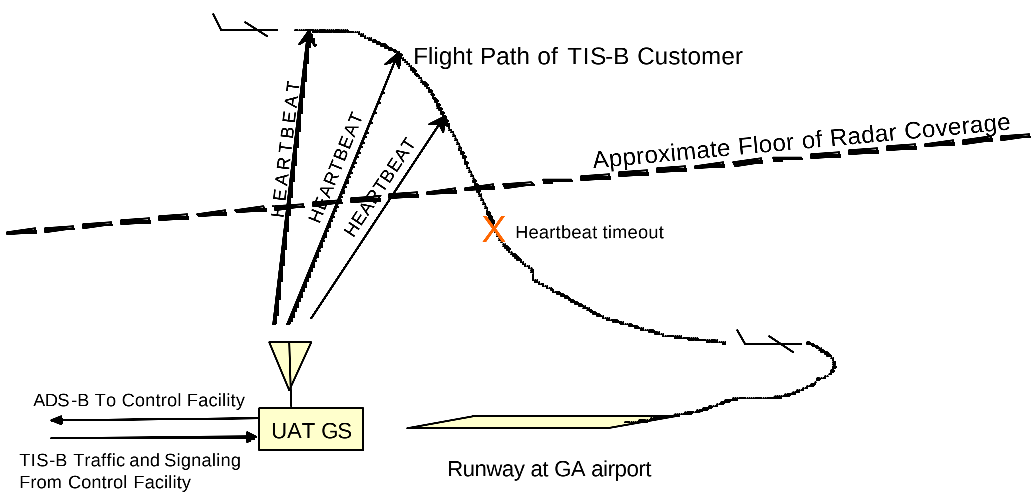

Figure 4-2: TIS-B Customer Leaving Service Through Floor of Radar Coverage

Most of the processing to support the TIS-B service status indication is performed by the TIS-B ground system. Figure 4-3 shows a logic flowchart that would provide the recommended status indications.

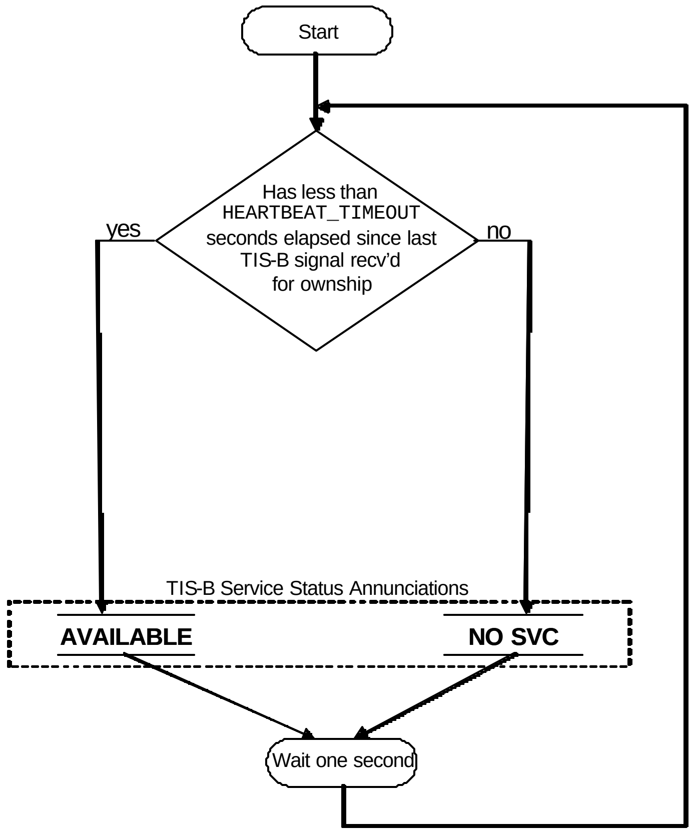

Figure 4-3: Avionics Processing Logic to Support the TIS-B Service Status Indication

4.1.3.2.3 Additional Points Relative to TIS-B Service Status

This service status approach is designed to provide high confidence of service for those that receive the "AVAILABLE" indication. This is because the TIS-B heartbeat messages provide confirmation of operation for the entire TIS-B system for the customer's immediate airspace environment. Even in cases where no traffic is visible on the display, the pilot has reasonable confidence the TIS-B system has no traffic in the customer's immediate proximity to depict since the heartbeat message is being provided. On the other hand, a "NO SVC" indication could result in the pilot still seeing traffic on the display. This could be for either of three reasons: 1) traffic is due to ADS-B air-air message reception not subject to the service status indication, 2) traffic is due to TIS-B message reception, but for traffic not in the immediate proximity of the TIS-B customer aircraft, 3) the TIS-B customer is skirting the edge of the TIS-B service volume resulting in possible intermittent depiction of proximate traffic.

Providing a TIS-B service status indication can be fully supported only for TIS-B customers who are also ADS-B participants.

***Note**: The topic of TIS-B service status indication is expected to be further refined in the next update to [TIS-B MASPS]. It is possible that when published, the standards may differ somewhat from the preliminary information presented in this section.*

4.2 Consideration for Processing and Display of FIS-B Products

Guidance applicable to the processing and display of uplinked FIS-B products is provided in Section 3.8.1 of [FIS-B MASPS].

One additional set of guidance beyond [FIS-B MASPS section 3.8.1] is applicable to the NEXRAD Graphics Product discussed in Section 2.3.3.2. If the cockpit display of the NEXRAD Graphics product is updated in an incremental fashion, the following guidelines apply (i.e., as APDUs with new data (later observation time or cut-off time) are received, they are integrated directly into the cockpit display, replacing that incremental portion of the display contained in that APDU):

- The product time displayed shall be the time of the oldest source product (mosaic or individual observation) that contributes to the displayed image.
- The time span between the oldest and newest source product contributing to the displayed image shall not exceed 10 minutes. Portions of the image that exceed this 10 minute requirement shall be depicted as missing data.
- This incremental display technique should not be used as the basis for a Sequential or Looping Product.

***Note:** This guidance seeks to limit the maximum age difference of the data contained in these displays. This guidance will be included in the next update to [FIS-B MASPS].*

5 Acronyms

ACL	ASA Capability Level
ADS-B	Automatic Dependent Surveillance-Broadcast
APDU	Application Protocol Data Unit
ASA	Aircraft Surveillance Applications
ASAS	Airborne Separation Assistance System
ASSAP	Airborne Surveillance and Separation Assurance Processing
ATC	Air Traffic Control
CDTI	Cockpit Display of Traffic Information
CFR	Code of Federal Regulations
DLAC	Data Link Application Coding
FCS	Frame Check Sequence
FIS	Flight Information Services
FIS-B	Flight Information Services-Broadcast
GSA	Ground Surveillance Applications
HDLC	High Level Datalink Control
ICAO	International Civil Aviation Organization
IMC	Instrument Meteorological Conditions
MASPS	Minimum Aviation System Performance Standards
MCDU	Multi-function Control Display Unit
METAR	Meteorological Aviation Report
MOPS	Minimum Operational Performance Standard
NEXRAD	Next Generation Weather Radar
NOTAM	Notice to Airmen
RF	Radio Frequency
SAE	Society of Automotive Engineering
SF21	SafeFlight 21
SSR	Secondary Surveillance Radar
SUA	Special Use Airspace
TAF	Terminal Area Forecasts
TIS-B	Traffic Information Services-Broadcast
TOMR	Time of Message Receipt
UAT	Universal Access Transceiver
UI	Un-numbered Info
UTC	Universal Time Coordinated